



PRO-Active Computing

- Get Physical
- Get Real
- Get Out

Dr. David Tennenhouse, Director
Information Technology Office



A Brief History of Information Technology

Numeric Computation



Symbolic Processing



Interactive Computing



ITO



Success Stories



1965

1975

1985

1995

Timesharing

CTSS, Multics,
BSD, Unix

Graphics

Sketchpad

Internet & LANs

Arpanet,
Internet, ATM

Workstations

Lisp machine,
Xerox Alto,
Apollo, Sun

— Gov. Research — Industry Research ■ ■ ■ Industry Development — \$1B Business → Transfer of ideas or people

ITO



A Brief History of DARPA I.T.



Interactive Computing

1962- present (J. Licklider, B. Taylor, I. Sutherland)



Strategic Computing

1974- present (Bob Kahn)



**Artificial
Intelligence**
(Saul Amarel)



**High Perform.
Computing**
(Steve Squires)

1960's

1970's

1980's

1990's

ITO



DoD Impact



Interactive
Computing

Command &
Control

Strategic
Computing

C4ISR

High Performance
Computing

DOE, NSA,
NRO, etc.



Beyond Interactive Computing...

Lets “Declare Victory” on
Command & Control!

- Get Physical
- Get Real
- Get Out



PRO-Active Computing

“Declare Victory” on White Collar Computing

- Why?
- Why Now?
- How?

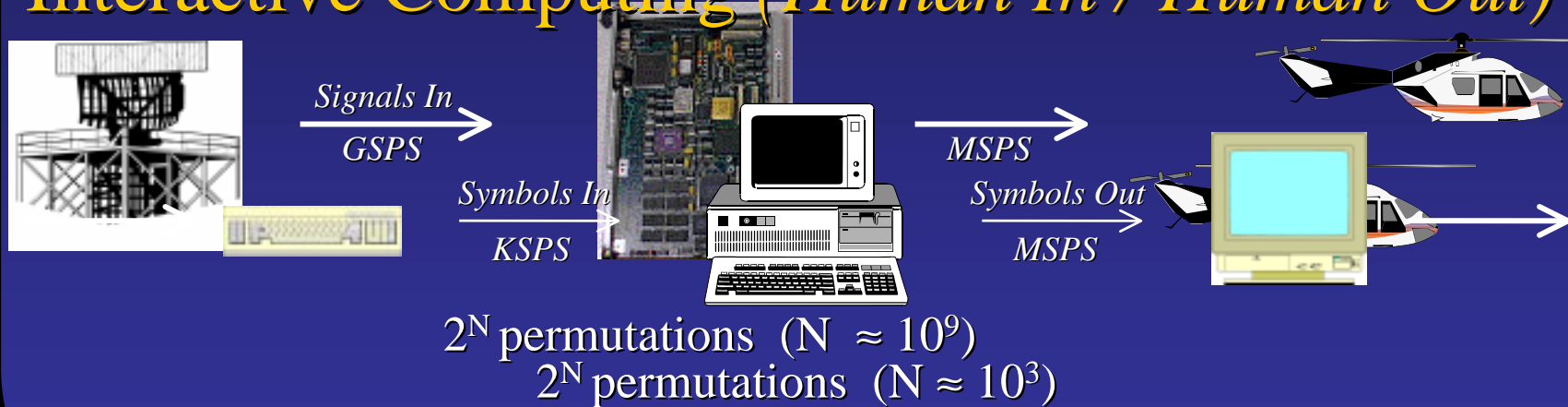


Why Be PRO-Active?



Where is our information coming from?
Where is it going?

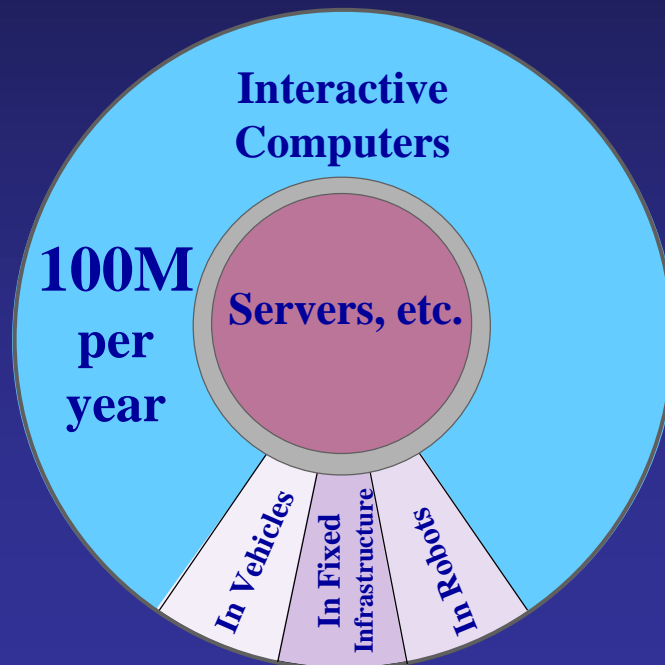
Interactive Computing (*Human In / Human Out*)



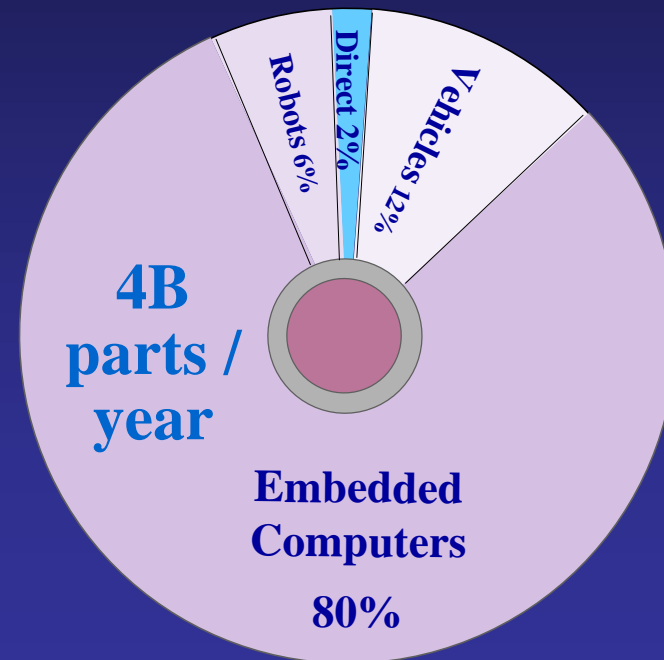


Where Will the Computers Be?

Where Has CS Focused?

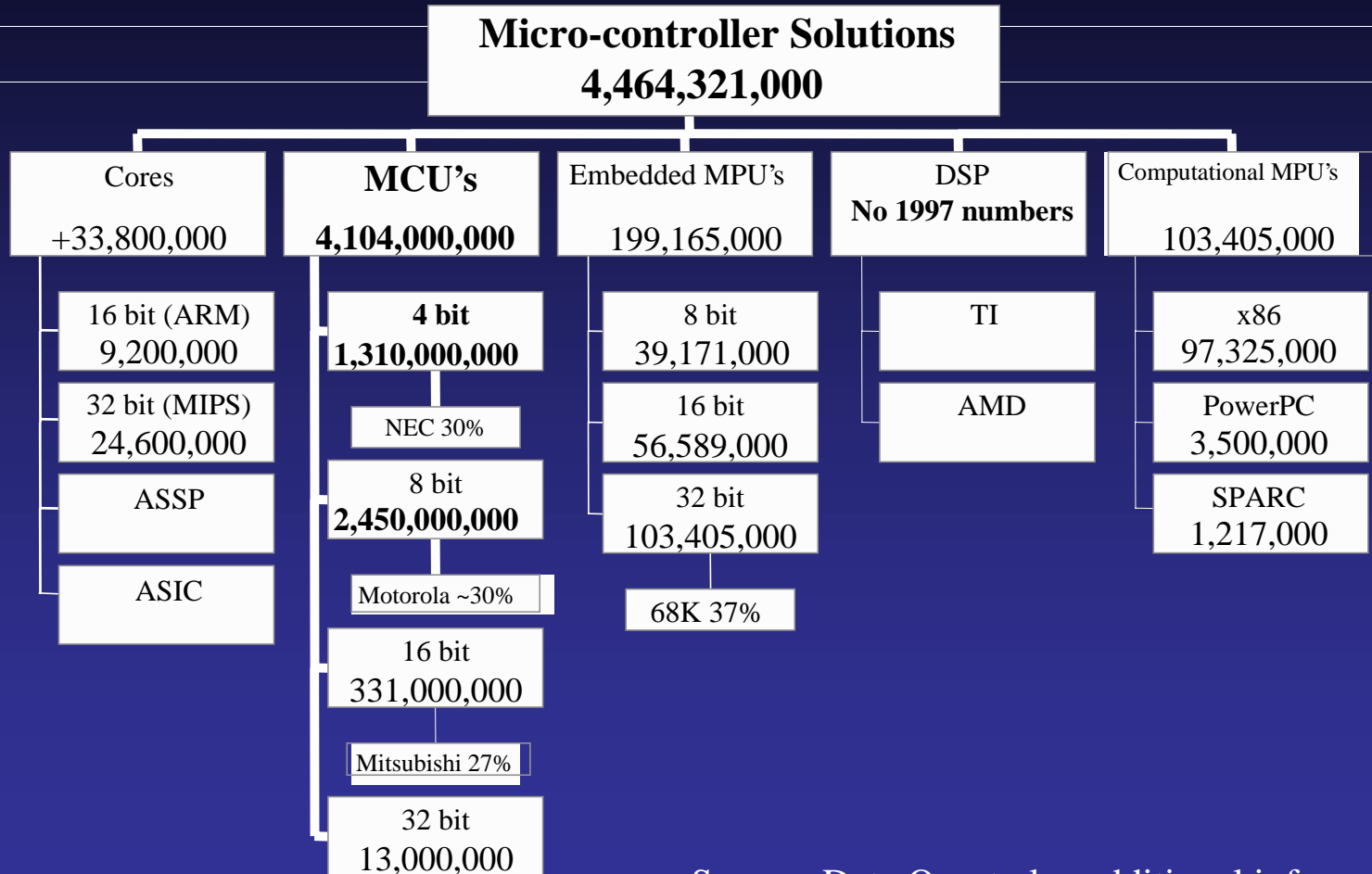


Where Are The Processors?





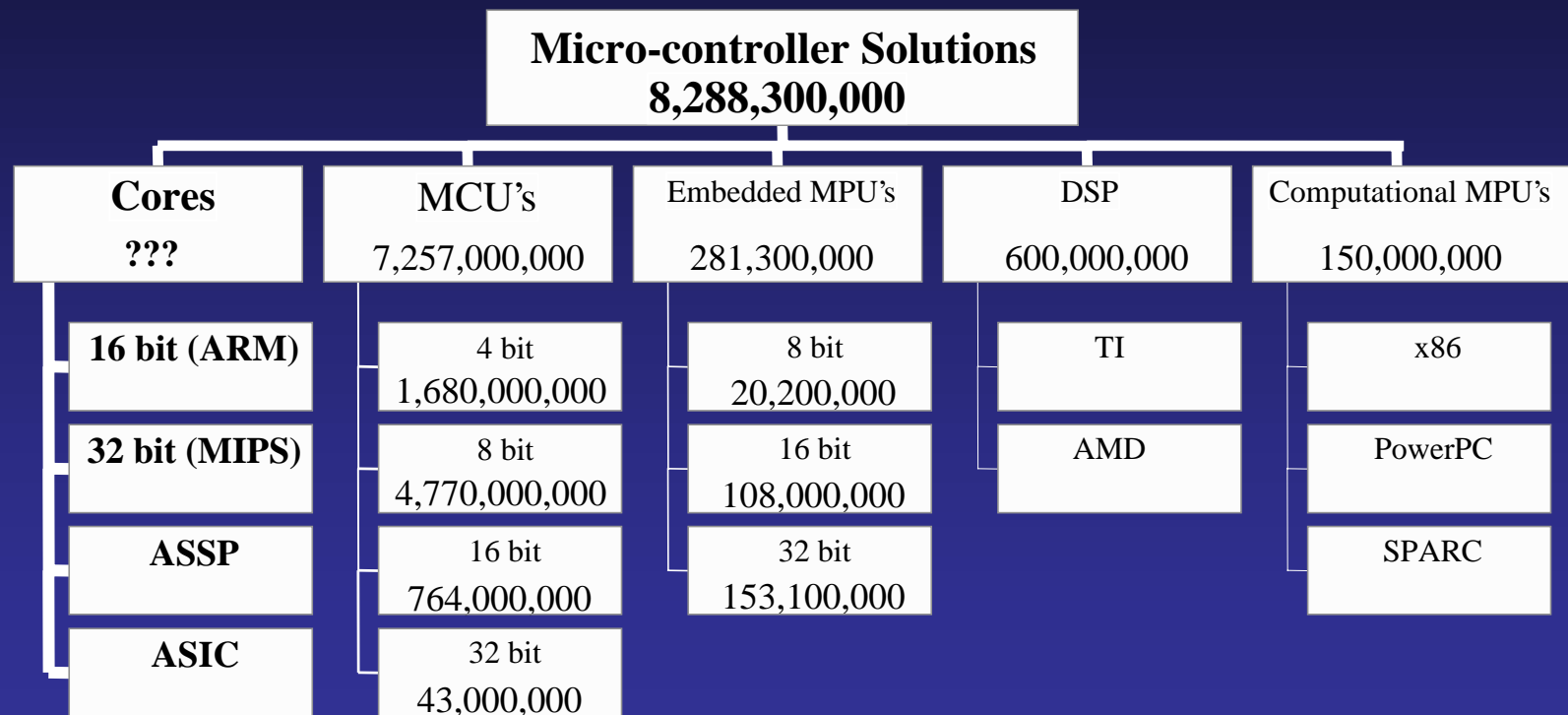
CPU Shipments In '97



Source: Data Quest plus additional information



Projected CPU Shipments In 2000



Source: Data Quest plus additional information



Why Now?

Inflection Points

- *Reinvention* of embedded processors
- *Deep Networking* of the missing 98%
- *Limits* of interactive computing



Isn't This The Same As Ubiquitous Computing?

- Human productivity is common objective
- However, ubiquitous computing remains centered on
 - Human-in-the-loop paradigm
 - White-collar applications



How Do We Move Forward?

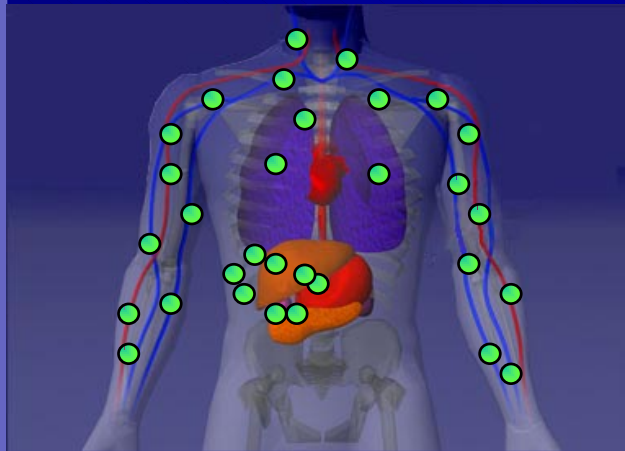
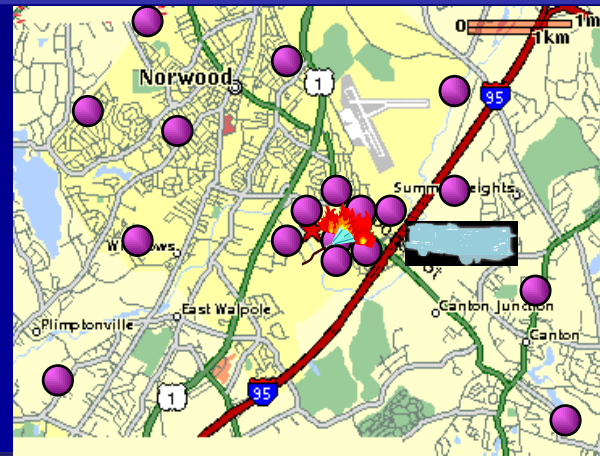
- Where are the opportunities?
 - Getting Physical
 - Getting Real
 - Getting Out



Get Physical



Attain pervasive
physical locality to
subjects of interest



Direct coupling to
the physical world
via networked
devices

Targets: Vehicles, Infrastructure, Factories, Human Body



Get Physical



Bridge the Physical and Virtual Worlds

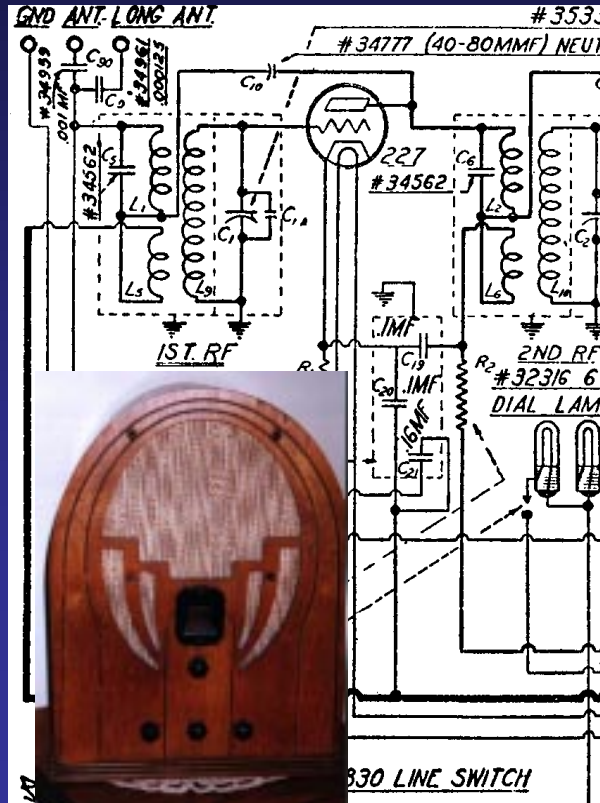
- Sample Challenges / Opportunities
 - Virtual Radios
 - Software-Enabled Control
 - National Scale Instrumentation
 - Sensor Information Technology



Virtual Radios

Getting
Physical

Edison's Radio



Turing's Radio

```
pages = (BlockSize/4096) +1;
if((guppi_open("guppi0",pages)) < 0 )
    exit(0);
guppi_start_rec();
for ( i=0 ; i< NumBlocks ; i++){
```

```
pdata = (char *)guppi_rec_buf();
for ( j=0 ; j< IntsPerBlock ; j++){
```

```
RealTap_ptr=RealTap;
ImagTap_ptr=ImagTap;
OutputDataReal=OutputDataReal;
OutputDataImag=OutputDataImag;
a=cos(TwoPi * FreqIn * index);
b=sin(TwoPi * FreqIn * index);
index += DecF;
for ( k=0; k< FilterSize; k++){
    OutputDataReal[k] = RealTap[k] * a + ImagTap[k] * b;
    OutputDataImag[k] = ImagTap[k] * a - RealTap[k] * b;
}
```

...



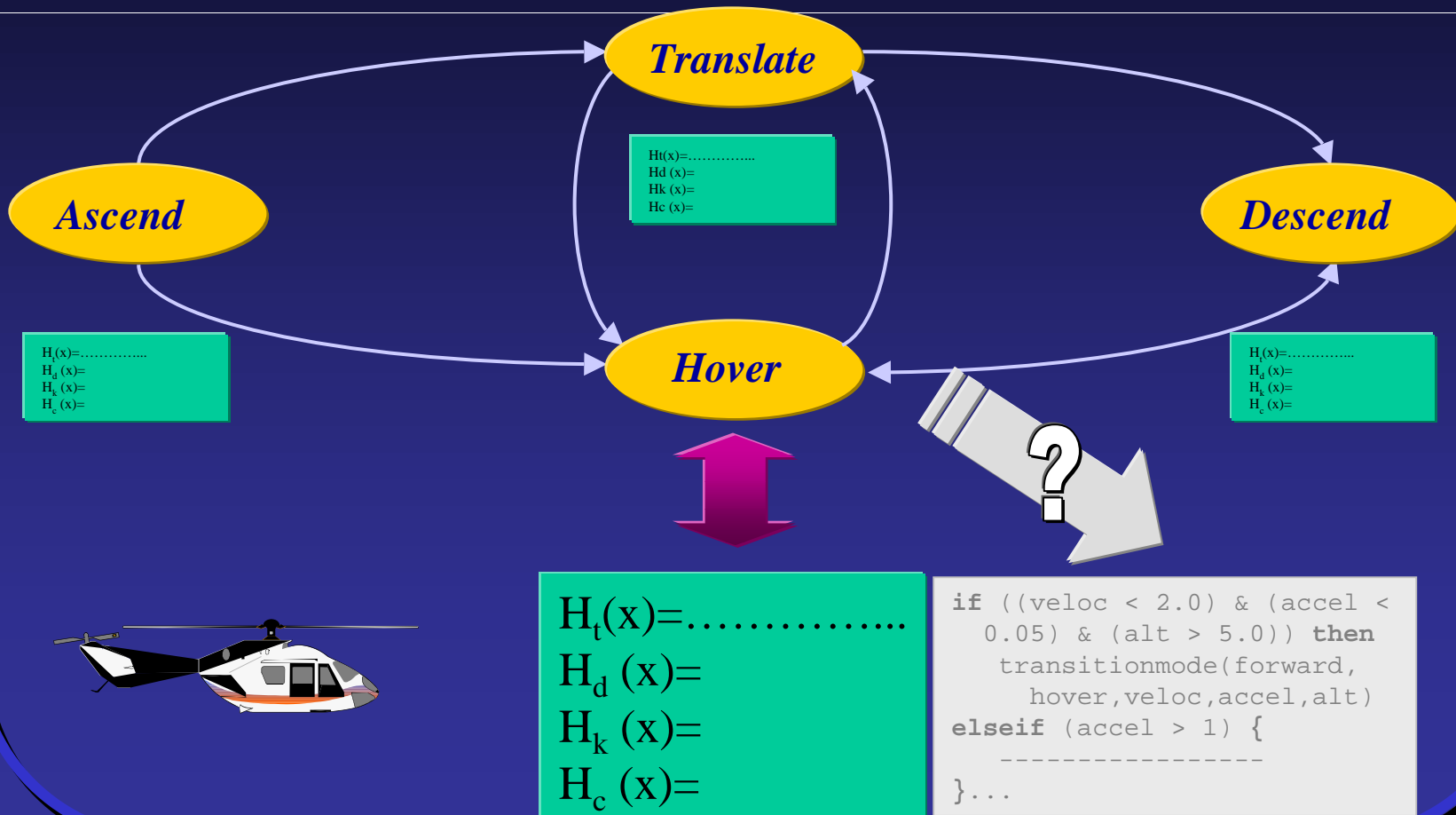
Disclaimer: "This is not an approved DARPA program. This alternative is under consideration."

ITO



Software-Enabled Control

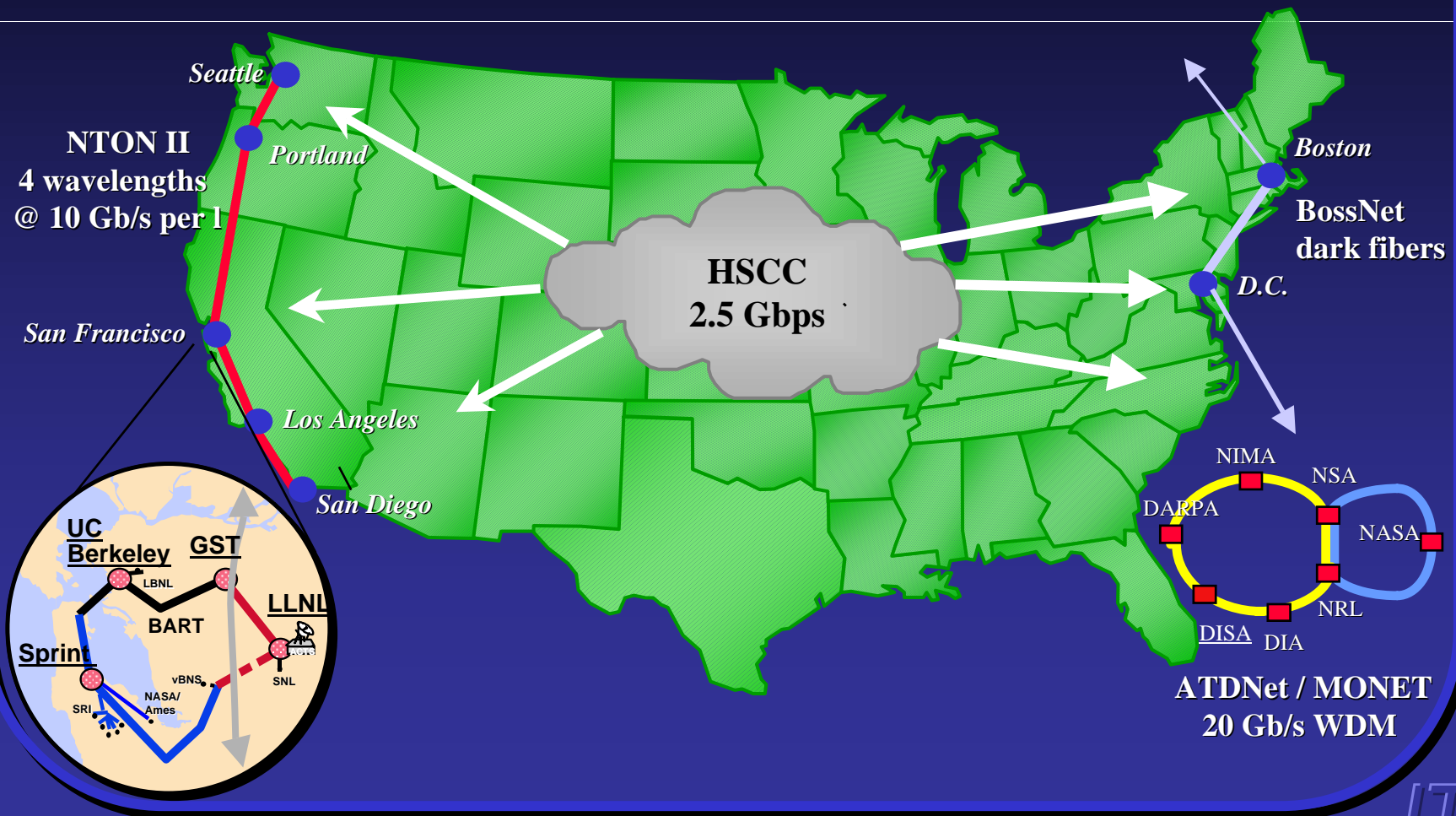
Getting Physical





National Scale Instrumentation

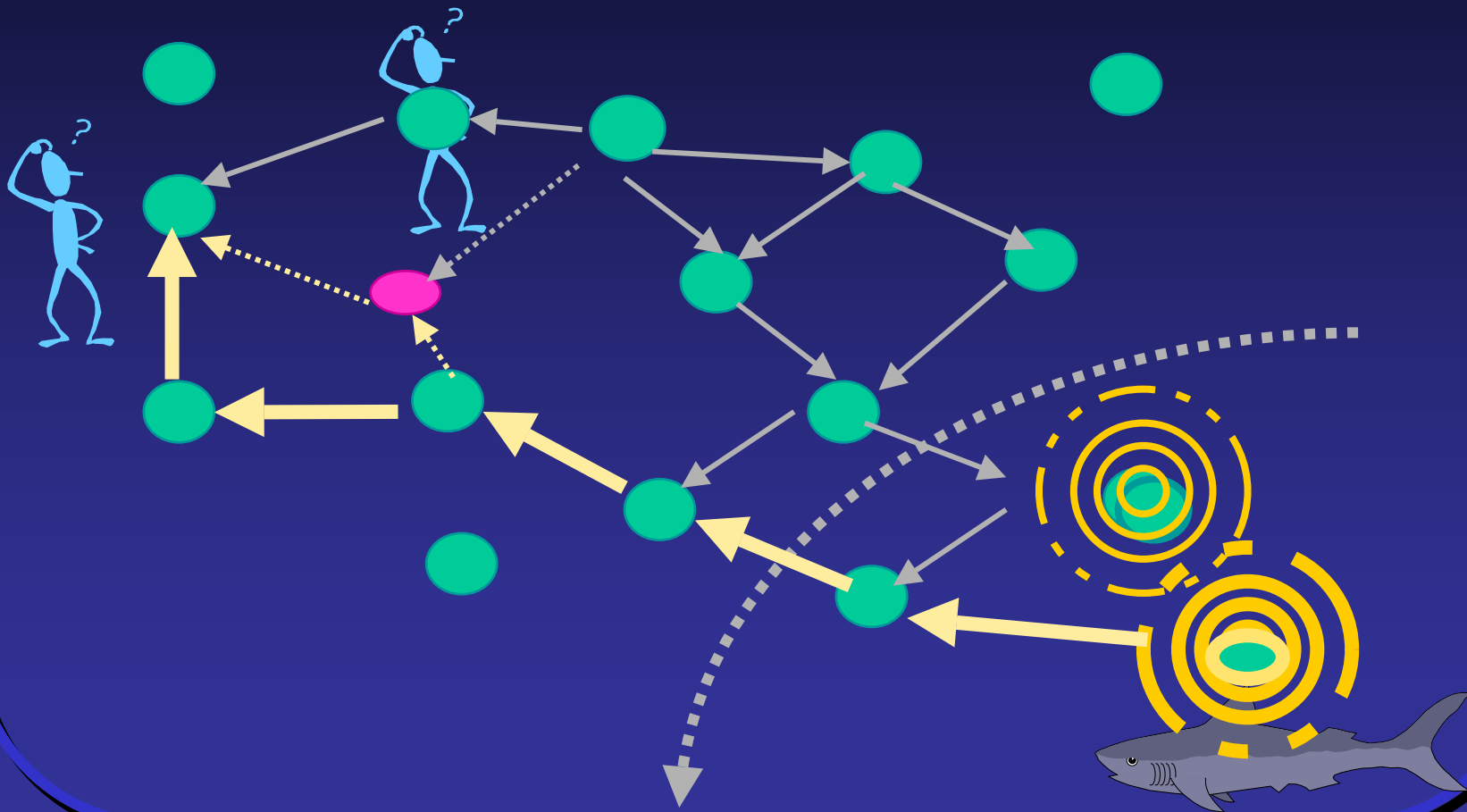
Getting Physical





Sensor Information Technology

Getting
Physical



ITO



First-Class Software for Embedded Systems

- Software to bridge the gap between single nodes and useful systems is missing ...
 - How do you enable “multi-tasking” of large collections of embedded nodes?
 - How do you “query” a sensor network?



Let's Get Real

Operate at Faster-Than-Human ($>10\text{hz}$) Frequencies

- Drive applications towards real-time.
- Squeeze latency out of every system
- Enable fine-grained, high frequency interaction across subsystems.



Getting Real



- Sample Challenges / Opportunities
 - Quorum Operating System
 - Faster-Than-Real-Time Simulation
 - Just-In-Time Hardware
 - PRO-Active Biology



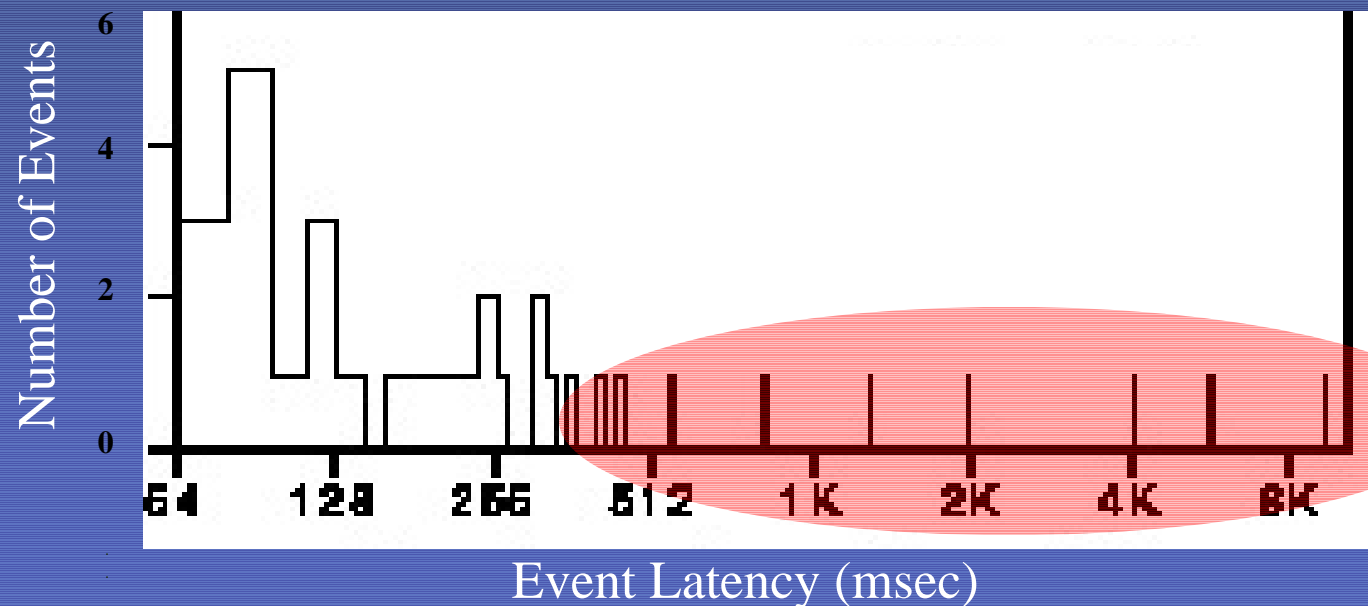
Quorum Enhancements to NT

Getting
Real

Dynamic Response to Mixed Workloads

Distribution of Event Latencies on NT 4.0

(Endo, et al, 1996)

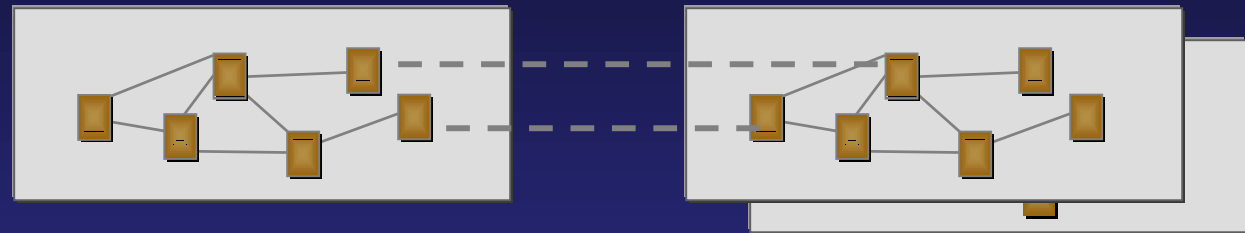




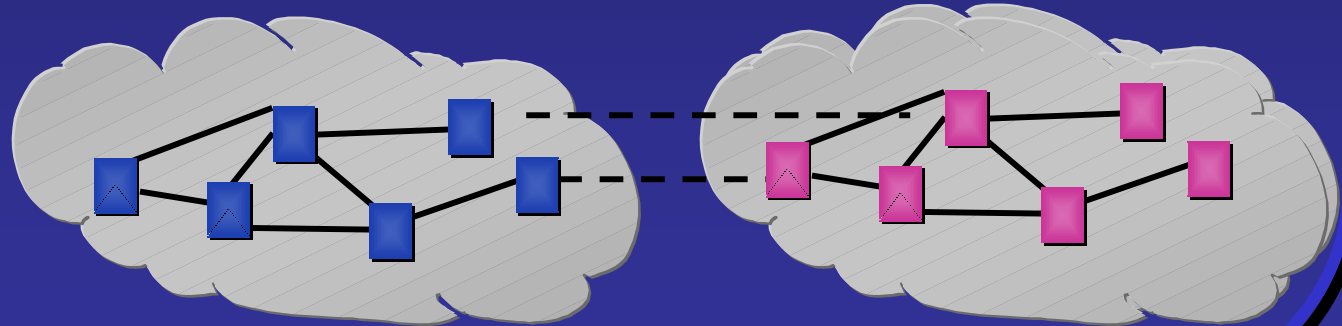
Faster-Than-Real-Time Network Simulations

Getting
Real

simulators



real world
networks



ITO



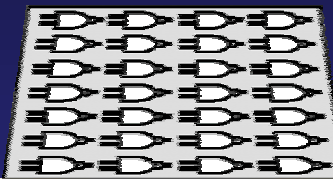
Just-in-Time Hardware

Getting
Real

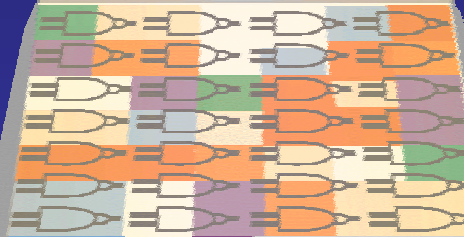
Application



Sea of Gates



Instantly “Wired”



Run-Time Configurable Computer

ITO



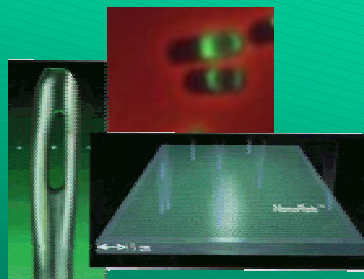
PRO-Active Biology

Getting
Physical

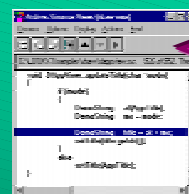
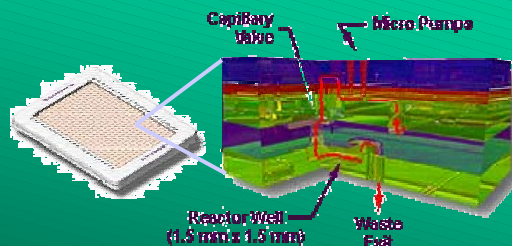
Real-Time
Monitoring



Lab-on-a-Chip



Access to
Experiments
in Progress



Interactive
Benchstation

Disclaimer: "This is not an approved DARPA program. This alternative is under consideration."

ITO



Getting Out



People are
Operators

People are
Users

People are
PRECIOUS

**Get the Humans Out /
Above the “Loop”**



Getting Out



Get the Humans Out / Above the “Loop”

- Sample Challenges / Opportunities
 - First Class Software for Robotics
 - Distributed Agents / Knowbots
 - “Above the Loop” Approaches to HCI



Robotics Research Without Building Robots(?)

Getting
Out

*Leverage the progress
in mechatronics*

Goal
**Many robots /
person**

*Proposed
Research*

State-of-the-Art
One robot /
person

State-of-the-
Practice
Several people /
robot

Develop the missing software



Teams Of Knowbots

Getting
Out

- Leverage mobile code (agents) to achieve autonomous negotiation of large scale problems.
 - faster-than-human speed
 - millions of knowbots / person
 - allocation good enough & soon enough



What About HCI?

Getting
Out

- What Has Worked?
 - Interactive HCI Platform \approx Computer
 - Single focal point / intermediary
- What about the PRO-active HCI?
 - How does a person direct thousands of devices? or millions of agents?



Getting Active

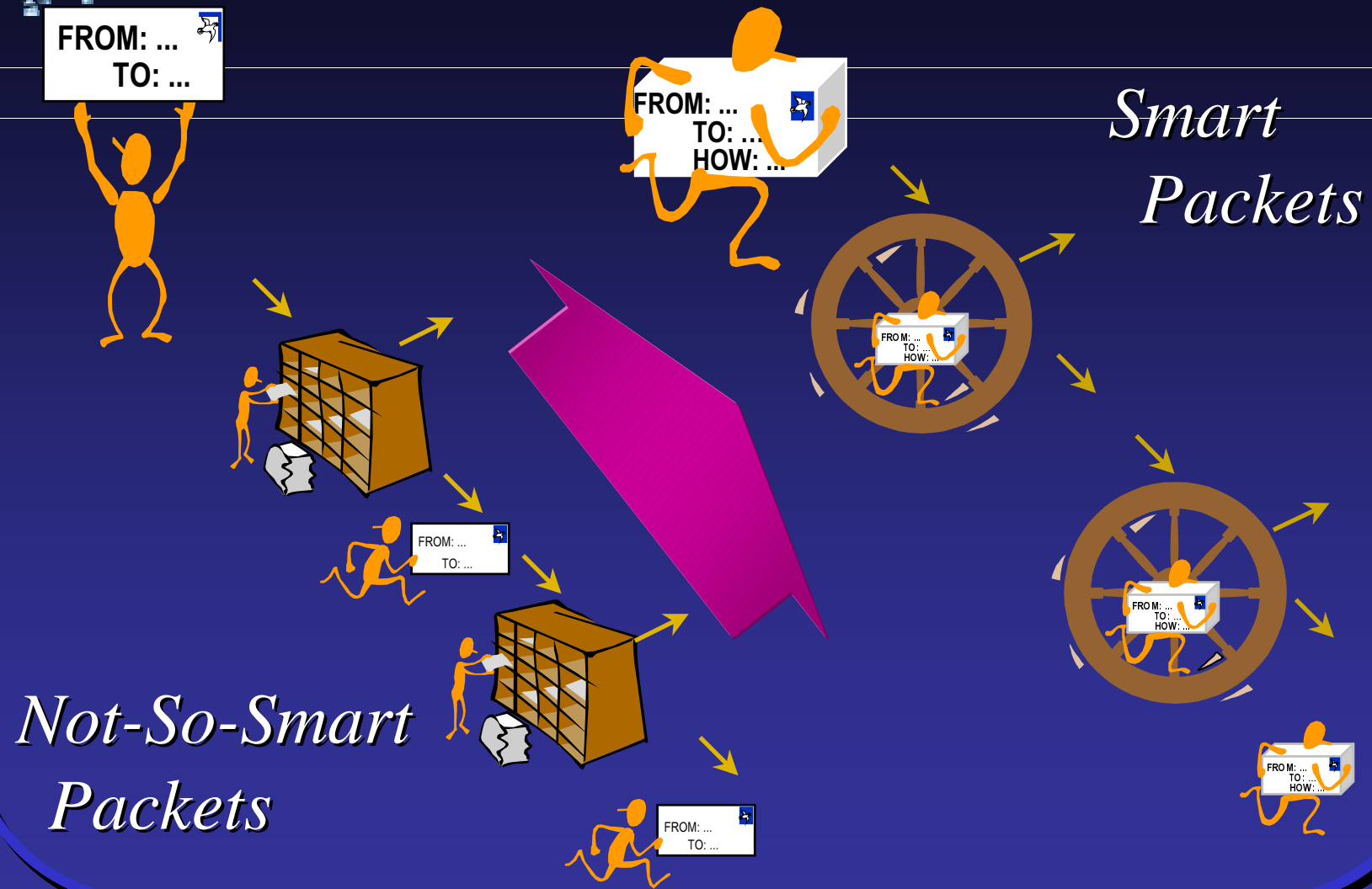


Java Is 5% of a Much Bigger Story ...

- Technical Challenges / Opportunities
 - Autonomous Knowbots
 - Active Networks
 - Active Software



Active Networks

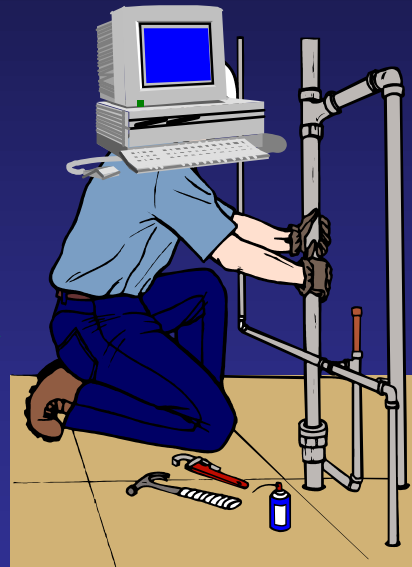




Active Software

Software That Reconfigures Itself *While Running*

changes in
environment,
needs



New
behavior,
new output

How does code mobility change the
way we think about software?

Disclaimer: "This is not an approved DARPA program. This alternative is under consideration."

ITO



Can We Get Physical / Real / Out / Safely?

➔ Yes...

but that's another story.



How Does PRO-Active Move DoD Forward?

- Protection from Biological Attack
- Dynamic Battlefield
- Affordable, Precision Target Engagement
- Mobile, Distributed C³
- Combined Manned & Unmanned Warfare



PRO-Active Computing: The Other 98%

- We have only addressed 2% of the CPUs!
- The other 98% are embedded
- How does the world change with:
 - 1,000 processors / person?
 - Too many to bother keeping track of?